CONDITIONS UNDER WHICH GONIOBASIS LIVESCENS OCCURS IN THE ISLAND REGION OF LAKE ERIE.*

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INTRODUCTION.

The distribution of *Goniobasis livescens* is so sharply defined in certain sections of the island region of Lake Erie and the situations in which it occurs are so varied in character that an examination into the factors involved naturally suggests itself. The conclusions offered here are based on observations recently made during several summers at the Lake Laboratory at Put-in-Bay. Quite a variety of conditions exists within the bay, and, because their proximity to each other made comparisons easy, the bay was carefully surveyed. This was followed by an examination of conditions throughout the island region. An attempt was then made to interpret the data in the light of a few simple experiments.

Much of the field work was done with the interested assistance of my wife and of a former student, Mr. E. L. Wickliff. I am also greatly indebted to Mr. Bryant Walker, who very kindly identified the snails.

OBSERVATIONAL DATA.

Put-in-Bay.

A rubble beach and a bar extending from it into Put-in-Bay at the latter's western extremity, both present sharp limits in the distribution of *Goniobasis*. The beach and one side of the bar are exposed to the lake; the opposite side of the bar faces the still water of a small cove.

The beach is composed of small stones, their size ranging from an average maximum of seventy-cubic inches to an average minimum of three cubic inches. They are washed constantly by waves which at times are quite severe. *Goniobasis*

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is practically absent. A few were found at one spot in ten inches of water on relatively large stones, i. e., averaging one hundred and sixty cubic inches. Just a few feet from this spot the beach makes a turn and faces the cove. In this undisturbed water, fourteen snails were collected from an area one foot square. They were at depths of two to four inches on stones averaging only eighteen cubic inches. Other animals found with them were the snail *Planorbis parvus* and the leech *Herpobdella punctata*. *Physa ancillaria* var. *magnalacustris** and parnid beetle adults and larvæ were also present but by no means as abundantly as on the exposed side of the beach.

The bar mentioned above is chiefly composed of small stones. The side facing the lake slopes gradually but the side toward the cove drops abruptly into deep water. *Goniobasis* was very scarce on the lakeward side. When found it was never in less than ten inches of water and it was always on the larger stones. Just around the free end, or nose, of the bar, where the lake waves could not be felt, the snails began to appear in less than ten inches of water on stones about forty cubic inches in size. Farther along, and distinctly on the cove side, specimens were common on the smallest stones, five or more to the linear foot. Some of them were barely covered with water. The portion of the bar nearest the beach is covered with one to two feet of water. Even here the snails are found on the coveward slope of the bar, where the force of waves from the lake is largely avoided.

Along the lakeward side of the bar, *Physa* was quite common and, in some spots, extremely abundant. Mayfly larvæ and caddis-worms were also present. On the cove side, none of these animals were as numerous, in fact the mayfly larvæ and the caddis-worms were decidedly scarce.

In this distribution the following points are clear: *Goniobasis* is more abundant in still water than in disturbed water; in the rough water they are on large stones or well beneath the surface, or both; in still places they are near the surface and may be on comparatively small stones.

These relations were compared with the conditions under which the snails occurred elsewhere in the bay. A few typical situations will be described.

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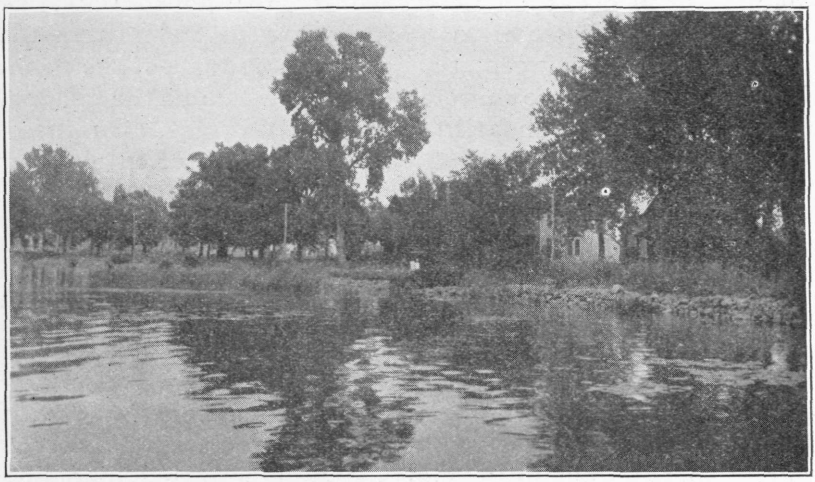
*Wherever Physa is mentioned this species is meant.

In the cove, just discussed, there is a pile of stones on the island shore. One side of this pile is well protected, the other side is exposed to whatever force the waves have left after they sweep across the bar. On the protected side of the pile, in water two inches deep or less, the snails were abundant on stones averaging eighteen cubic inches. On the exposed side, the snails were not so numerous (twenty-two of them in an area one foot square) and those present, were on stones averaging thirty cubic inches.



A FAVORABLE HABITAT.

SQUAW HARBOR, a well protected section of Put-in-Bay. Pond conditions are approached. Clumps of reeds (*Scirpus*) and water lillies (*Nymphaea*) can be seen in the picture. There is an abundant growth of submerged plants such as *Potomageton*, *Vallisneria* and *Myriophyllum*. The shore has been artificially faced with stones. *Goniobasis* is abundant among the stones near the surface.

Somewhat further along the shore of the bay, in a very well protected situation, there were one hundred twenty-nine snails in a square foot on stones four cubic inches in size, lying in four inches or less of water. By way of contrast, one may take a stretch of gradually sloping, stony beach, several hundred feet down the shore. The stones averaged four cubic inches and a small amount of sand was mixed with them. Upon occasion, this beach is swept by strong waves from the lake and, even on quiet days, there is a more or less constant ripple of water.

Goniobasis was occasionally seen in ten inches of water on larger stones, but not in water shallower than this. It is to be noted that *Physa* was fairly common and, therefore, the possibility that the sand acted upon *Goniobasis* unfavorably may be discounted.

A narrow channel cuts across the beach just described, into a small division of the bay called Terwilliger's Pond. At the entrance into this channel *Goniobasis* was present in two or three inches of water on stones one hundred to two hundred cubic inches in size, there being two or three snails on a stone. Individuals in this situation were exposed to waves from the lake and also to the sweep of a current, in and out of the pond, which at times became quite severe. One side of the channel is faced with the foundation beams of a bridge. On these, seven or eight snails occurred to a linear foot, often right at the surface of the water. The opposite side of the channel is bordered by an accumulation of small stones and, on these, *Goniobasis* was not found.

There is an indentation of the bay, known as Squaw Harbor, in which pond conditions are approached. It supports a rich growth of submerged vegetation, patches of reeds and pond lillies. The water is quiet even when the outer bay is considerably disturbed. The shore has been artificially faced with stone. *Goniobasis* is very commonly distributed along the shore. On the fine, silty mud of a well protected dike just within the entrance to Squaw Harbor there were approximately sixteen *Goniobasis* to a square foot in less than a foot of water. On the protected side of a gravelly point, at the entrance, fourteen of the snails were found in a square foot, but there were none on the opposite, exposed side.

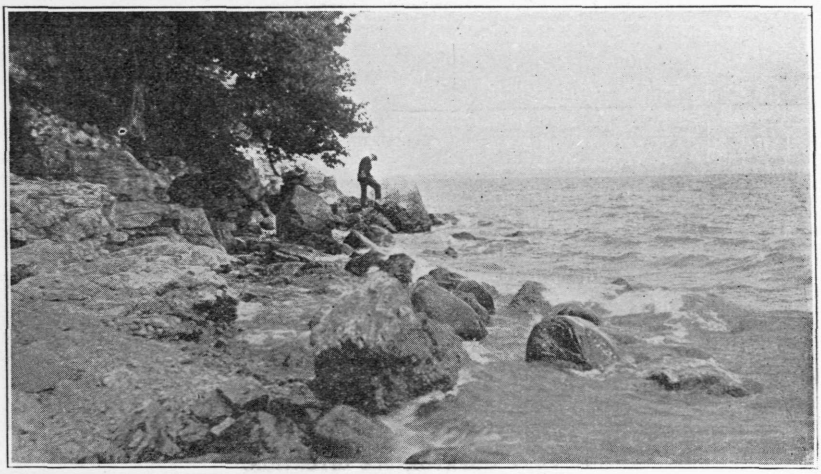
The most common form found with *Goniobasis* on the stony shore of Squaw Harbor, was a freshwater sponge, *Spongilla* (sp?). *Planorbis trivolvis* and parnid beetle larvæ were less frequent and were found in about equal numbers. Crayfish, and the snails *Physa ancillaria*, *Planorbis parvus*, *Lymnaea humilis* were also present.

Extending across the entrance to Put-in-Bay is an island with a rocky shore. *Goniobasis* is decidedly scarce on the side facing the lake. When found it is a foot or more under the surface. It is abundant on a protected, stony bar extending from the island into the bay.

A detailed account of other parts of the bay would be essentially a repetition of what has already been given. In the bay, as a whole, *Goniobasis* was most abundant in protected situations. If present in exposed places, it was rarely less than a foot under the surface and, then, only on larger objects. When protected it was close to the surface on a variety of substrata.

The Island Region in General.

The distribution throughout the island region was taken up in the light of these observations. Certain critical areas were studied in detail.



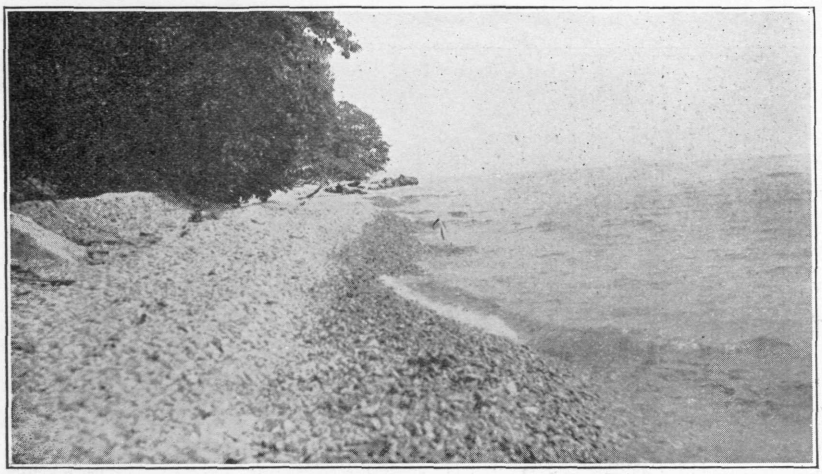
DIFFICULT CONDITIONS.

OLD HEN ISLAND, a fully exposed situation with rocky and bouldery shore. *Goniobasis* is scarce and when found it is usually 10 to 15 inches beneath the surface.

The eastern extremity of South Bass Island is a solid ledge of shelving rock, exposed to the full sweep of storms. On it, large boulders and smaller stones are scattered. A total of twenty *Goniobasis* was found here. They were taken, at different depths, in three different areas of a foot square. Accompanying forms were larvæ of stone flies, mayflies, caddis flies, parnid beetle larvæ, midge larvæ, a few *Physa ancillaria* and leeches. In calm weather, Goniobasis was distributed without much reference to the type of substratum. When the

water became rough, those found at the surface were restricted to the boulders and solid rock. The snails were found on smaller stones, only if the latter were ten or more inches under water, or else wedged firmly among larger objects near the surface. In extremely rough weather the snails passed to the protected sides of the boulders or to deeper water, in which case they were found on both large and small stones.

Near the southwest point of Middle Bass Island, on a fully exposed ledge of rock, *Goniobasis* was found only on the lower and, therefore, deeper parts of boulders. In four small areas



A VERY UNFAVORABLE SITUATION.

EAST SISTER ISLAND, a fully exposed rubble beach. *Goniobasis* was not found in such situations.

examined, only four *Goniobasis* were found, and these were in water two feet deep. Other forms on this ledge, usually in shallower water, were *Physa ancillaria*, *Lymnaea humilis* (most abundant), leeches, the larvæ of parnid beetles, caddis flies, mayflies and midges. All of them were common.

Ten miles to the north of Put-in-Bay, there is a group of four small islands, three of them hardly more than exposed ledges, known as the Hen and Chickens. On the Big Chicken, there is a ledge covered with stones and boulders. A few scattered *Goniobasis* were found on the boulders, none were on the stones. Along another side of the island, there were no large stones and

no *Goniobasis* were found. *Physa ancillaria* and the larvæ of caddis flies and mayflies, were quite common.

At the Old Hen, in rough water, the snails were scarce, even in fifteen inches of water and on stones having cubic dimensions of one hundred to two hundred and forty inches. In the protection of a dock, where the water is disturbed only in severe weather, and from but one direction, *Goniobasis* was very abundant at the surface on stones twelve to twenty cubic inches in size.

At West Harbor, on the mainland, five miles from South Bass Island, there is a sandy shoal. The sand is thrown into ridges and troughs parallel with the shore and at right angles to the waves. *Goniobasis* is quite common in the troughs, where the water is often waist deep. It is not found on the ridges unless the water is at least knee deep. The only other forms found in this habitat were the snails, *Pleurocera* (sp?) and *Campeloma* (sp?), an occasional midge larva and a few burrowing mayflies.

Discussion.

The situations which have been described give a typical picture of the conditions in the island region. In general the habitats are similar to those described by other observers for other localities. That is, *Goniobasis livescens* is found on exposed, rocky shores and also in more protected situations. However, its relative abundance in these two types of environments in Lake Erie does not agree with certain reports for other localities. In Oneida Lake it is most abundant on exposed shores (F. C. Baker, '16). It is similarly reported for the Saginaw Bay region (H. B. Baker, '15), and for the Georgian Bay region (Robertson, '11). In Lake Erie it is most numerous in protected situations. In them, it is near the surface without much regard to the nature of the substratum. The relatively few individuals living in exposed places are usually found ten inches or more beneath the surface. When they are near the surface they are on a firm substratum; lower down they may be on smaller and less firmly placed objects.

Experiments.

Any discussion of the factors involved in this distribution must consider the rather obvious correlation which exists between the wave action, the depth of the water and the nature

of the substratum. The possibility of variation in H-ion concentration or in carbon dioxide was taken into consideration, but no correlation was found to exist. Food was also considered as a factor but conditions in areas well inhabited by *Goniobasis* were similar to those in which it was less numerous.

Indirect Effect of Waves.

The two most obvious ways in which waves might influence snails, are either, indirectly, by moving the substratum, or directly, by moving the snails themselves. There is reason for thinking that both methods are operative. With regard to the first, it has been pointed out that the size and stability of the objects to which the snails were attached increased rather directly with exposure to wave action. A small stone is easily moved to and fro, a large one is not. With this in mind, a few simple experiments were performed.

I. A firmly wedged stone, one hundred twenty-six cubic inches in size, with a number of *Goniobasis* on it, was struck until it chipped. The stone did not move and none of the snails dropped off.

Another stone, two hundred sixteen inches in size, also firmly placed, was hammered for five minutes, the stone chipping in the process. It did not move. Only one snail out of ten dropped off and that one was near the spot being struck.

II. A stone, two hundred ten cubic inches in size, lying next to the stones of the first experiment but not firmly placed, was struck. The stone moved at the first tap and several snails on it dropped off. A stone, seventy-two inches in size, was tapped. Five snails were on it. The stone moved perceptibly. Three snails dropped off immediately and all were off at the end of thirty seconds.

A number of other tests, similar to the foregoing, were made. The results were uniformly the same. Whenever the stones were jarred sufficiently to cause their perceptible movement, the snails dropped.

Very evidently, an oscillatory movement of the substratum influences the snails in an unfavorable manner. And, in consequence, such a movement of the substratum brought about by wave action, must be considered as one of the factors, indeed, a very important factor controlling distribution.

Direct Effect of Waves.

This does not obviate the possibility that *Goniobasis* is influenced directly by the waves. Bearing upon such a possibility is the fact that the snails migrate vertically with changes in the degree of wave wash. When the water is quiet, or gently lapping, *Goniobasis* is a common object at the surface except where a gradually sloping substratum, in rather shallow water, tends to magnify the surface effects of small waves. As the water becomes markedly disturbed the snails move beneath the plane at which the waves break or, if the object to which they are attached is large enough to afford protection, they merely move around to the side opposite that from which the waves strike. However, it should be noted that the snails also do not leave these larger objects and, furthermore, that in troubled waters the snails are found only on the larger and more firmly placed objects for some distance below the surface, although they may not be in a protected situation when beneath a level where waves break.

This last fact serves to bring out the point that, in considering the direct effect of waves, a distinction must be made between the influence of the washing or breaking of waves, at the surface, and the subsurface wave motion. Individuals at the surface where waves break, receive a sudden blow on one side without anything commensurate to support them on the opposite side. Not only that, but they are frequently subjected to alternate blows on opposite sides in quick succession. The subsurface effect differs; there is water on all sides; the passage of the wave somewhat resembles a current. In the case of a current its full force may be just as severe as a blow delivered by a breaking wave, but its strength is usually gathered gradually and alterations in intensity take place in the same way. In this connection, it is worth noting that the snails on the foundation beams of the bridge, previously mentioned, did not change their position, when a current rushed by them with considerable force. This behavior is, of course, in line with the reaction of *Goniobasis* in streams. There it is frequently, found on firmly placed stones in rapids. (Shelford, '13). The behavior also corresponds with what has just been mentioned, namely, that they remain on firmly placed stones beneath the surface, where waves sweep across them, but do not break.

A few simple experiments were tried to test the reaction of *Goniobasis* to movements of the shells, such as might be caused by water striking it.

I. Eight snails on a horizontal surface had the apex of the shell moved back and fourth through a distance of half a centimeter for five minutes. The snails reacted in two ways: they either began to glide over the stone or else they remained at rest and assumed a generally tense condition of the body, the latter being detected by the degree of resistance to the movements of the shell. These two modes of reaction sometimes alternated. Six of the snails stayed on the stone for five minutes; two of them dropped off at the end of two or three minutes. When the stone was moved by tapping, four of the snails fell off immediately and one dropped at the end of fifteen seconds.

II. Three snails, on a perpendicular surface, had their shells moved as in the preceding experiment. Two of them dropped off immediately and one remained for five minutes. Movements of the stone caused it to drop immediately.

III. Four snails, on a surface inclined 45°, were treated as in the two preceding cases. Two of them dropped off at once. One dropped at the end of thirty seconds. One remained for five minutes, at the end of which period, movement of the shell was stopped. When the stone was moved this snail dropped off.

IV. A number of snails were now tested to determine the effect of a sudden blow. Ten snails were struck suddenly, although as far as possible with no more violence than that of the oscillatory movement at its height. Eight snails dropped off at once and two of them fell at the second blow.

Discussion.

The results obtained from these experiments apply, of course, to the question of the movement of the substratum as well as to that dealing with the direct effect of wave action. It is clear that when both conditions are possible, an oscillation of the substratum is of more importance in determining the presence of *Goniobasis*, at a particular spot, than is an oscillatory movement of merely the shell and visceral mass. It is also clear that the snails do not maintain themselves against a sudden blow delivered to the shell. This is in agreement with what has been said regarding the effect of waves at the surface. And further, it is evident that the snails cling more readily to a horizontal surface than they do to a sharply inclined surface.

When we consider more in detail, why the snails should be so extremely sensitive to movements of the entire body caused by oscillations of the substratum and comparatively tolerant of movements due to the swinging back and forth of merely the visceral mass it is to be remembered that in snails the organ of equilibrium, i. e., the otocyst, is in the foot. Swaying of the substratum would thus stimulate this organ. It develops therefore, that *Goniobasis'* sense of equilibrium can be considered a factor of importance in the selection of a habitat.

With regard to the inability of *Goniobasis* to resist wave wash, the shape and size of its foot in respect to the shape and size of its shell is presumably a matter of importance. A comparison of the behavior of *Physa* and *Goniobasis* may be helpful in this connection. *Physa* lives where waves break and ripple, that is, in the very conditions which *Goniobasis* avoids. When one compares the morphological difference between these two snails, it is readily observable that the comparatively short and approximately square foot on *Goniobasis* coupled with its massive and prominently projecting shell must afford a poor holdfast, whereas, the long and slender foot of *Physa* coupled with its relatively low, rounded shell is a much better organ of attachment.

In connection with the fact that in Lake Erie *Goniobasis* is most abundant in protected habitats it should be noted that in streams it is typically a member of a rapids association. (Shelford, '13). In a body of water such as Lake Erie a rapids environment exists under conditions which *Goniobosis* can not readily tolerate. In a lake, a rapids environment is produced by the wash of waves; in a stream it is caused by a current. Waves deliver sudden, intermittent blows. These *Goniobasis* cannot withstand. Waves also cause an oscillation of movable stones. *Goniobasis* is sensitive to an oscillation of the substratum. The force of a current is relatively constant and alterations in strength are relatively gradual. *Goniobasis* can accommodate itself to such conditions.

The habitat preferences of *Goniobasis livescens* in the Lake Erie island region can thus be harmonized with the well known fact that it is a typical member of a rapids association in streams, by reason of the fact that the relatively constant current of a stream does not introduce the two disturbing factors of sudden blow or oscillating substratum.

SUMMARY.

In the Lake Erie island region *Goniobasis livescens* inhabits both exposed and protected situations. It is most numerous in protected places.

In general, the more exposed the habitat the larger the object to which the snails are attached or, within certain limits, the farther beneath the surface it is found.

With increasing degree of protection the snails are found nearer the surface and are distributed within the habitat with less regard to the nature of the substratum.

Wave action is the controlling factor in distribution. Its influence is felt in two ways: (a) directly by striking the snails, (b) indirectly by causing an oscillation of the substratum. Where both conditions are possible, experiments indicate that oscillation of the substratum is of the greater importance, apparently because such oscillation stimulates the organ of equilibrium.

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